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(54) **FILTERING OUTPUT FROM OPERATIONAL COMMANDS EXECUTED ON A NETWORK DEVICE**

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H04L 12/24 (2006.01)

(52) **U.S. Cl.**
CPC ***H04L 43/045*** (2013.01); ***H04L 41/0604*** (2013.01); ***H04L 43/00*** (2013.01); ***H04L 43/028*** (2013.01); ***H04L 43/04*** (2013.01); ***H04L 43/06*** (2013.01); ***H04L 43/08*** (2013.01); ***H04L 43/0876*** (2013.01); ***H04L 43/14*** (2013.01); ***H04L 43/18*** (2013.01)

(58) **Field of Classification Search**
CPC G06F 17/30864; G06F 17/5036; H03M 13/05; H04L 1/0015; H04L 12/2809; H04L 12/2856; H04L 41/145; H04L 43/00; H04L 43/028; H04L 43/04; H04L 43/045; H04L 43/06; H04L 43/08; H04L 43/0876; H04L 43/14; H04L 43/18; H04L 41/0604; H04W 24/08
See application file for complete search history.

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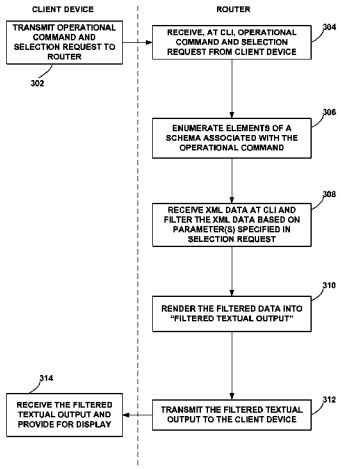
(57) **ABSTRACT**

In general, techniques are described to enable selective viewing of data output in response to a command. The techniques provide generic mechanisms to filter output solicited by commands supported by current and future implementations of an interface. An example device receives from a client device an input comprising an operational command a selection request that specifies a field identifier. A schema enumeration module of the device assigns a unique element number to each element of a class of elements defined by a schema, forming an enumerated schema. An interface of the device receives data conforming to a data description language, and a filtering module filters the textual output by mapping the field identifier specified in the selection request to a unique element number of the enumerated schema. A rendering module renders the filtered data into filtered textual output. The device transmits the filtered textual output to the client device.

22 Claims, 3 Drawing Sheets



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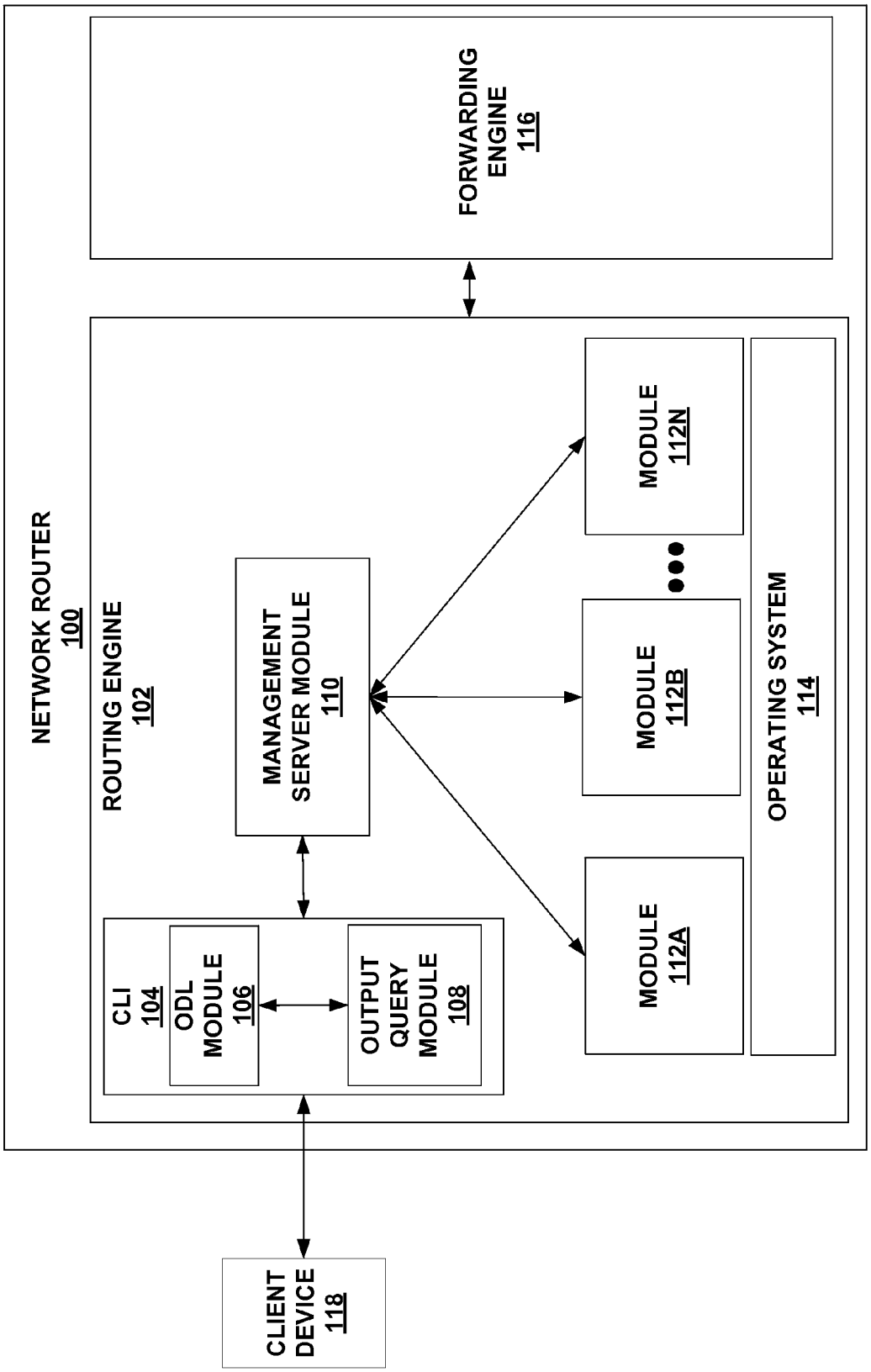
NETWORK ROUTER
100
FORWARDING ENGINE
116
ROUTING ENGINE
102
MANAGEMENT SERVER MODULE
110
MODULE
112N
MODULE
112B
MODULE
112A
OPERATING SYSTEM
114
CLI
104
ODL MODULE
106
OUTPUT QUERY MODULE
108
CLIENT DEVICE
118

FIG. 1

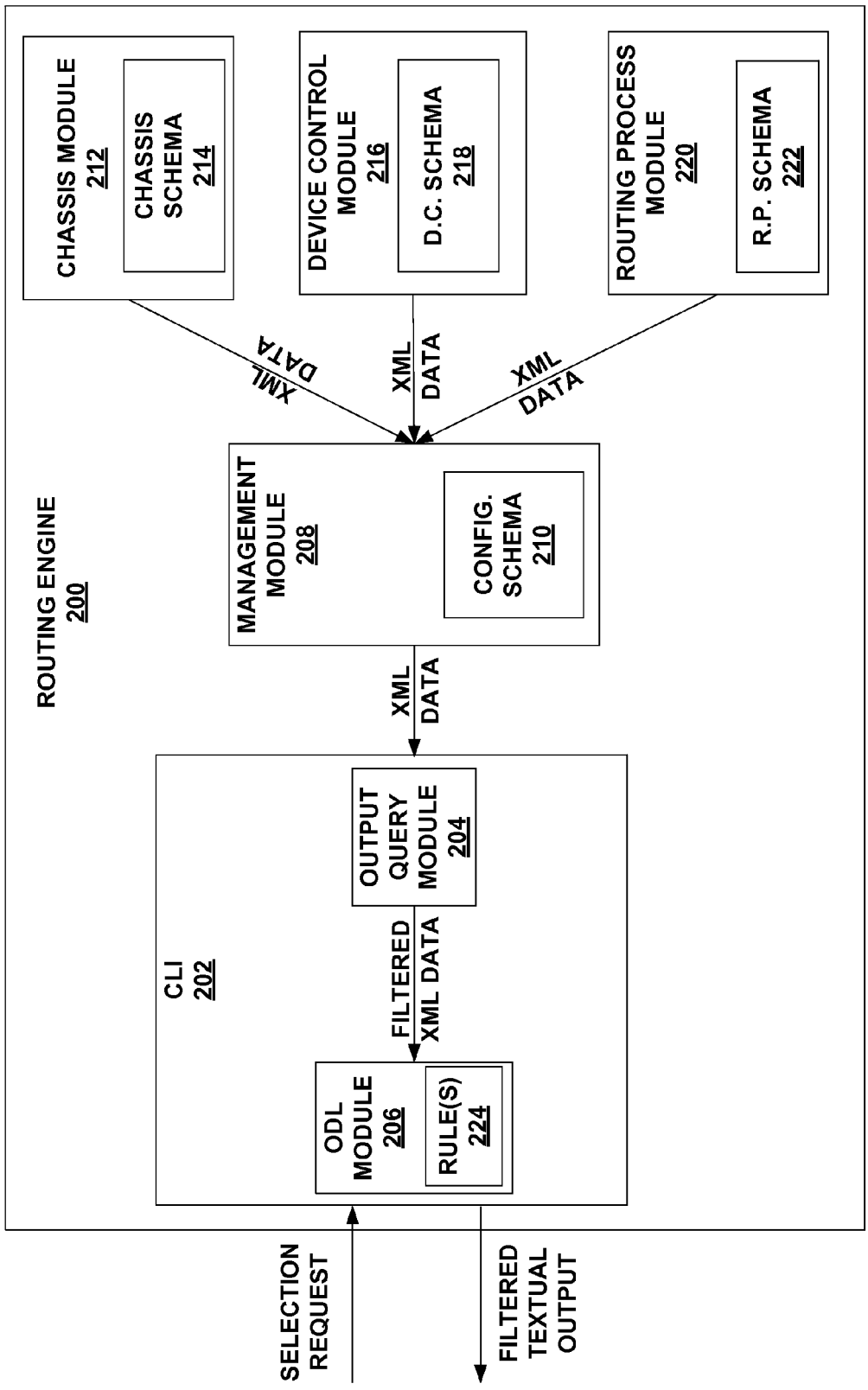
ROUTING ENGINE
200
CHASSIS MODULE
212
CHASSIS
SCHEMA
214
DEVICE CONTROL
MODULE
216
D.C. SCHEMA
218
ROUTING PROCESS
MODULE
220
R.P. SCHEMA
222
XML DATA
XML DATA
XML DATA
MANAGEMENT
MODULE
208
CONFIG.
SCHEMA
210
XML DATA
CLI
202
OUTPUT
QUERY
MODULE
204
FILTERED
XML DATA
ODL
MODULE
206
RULE(S)
224
SELECTION
REQUEST
FILTERED
TEXTUAL
OUTPUT

FIG. 2

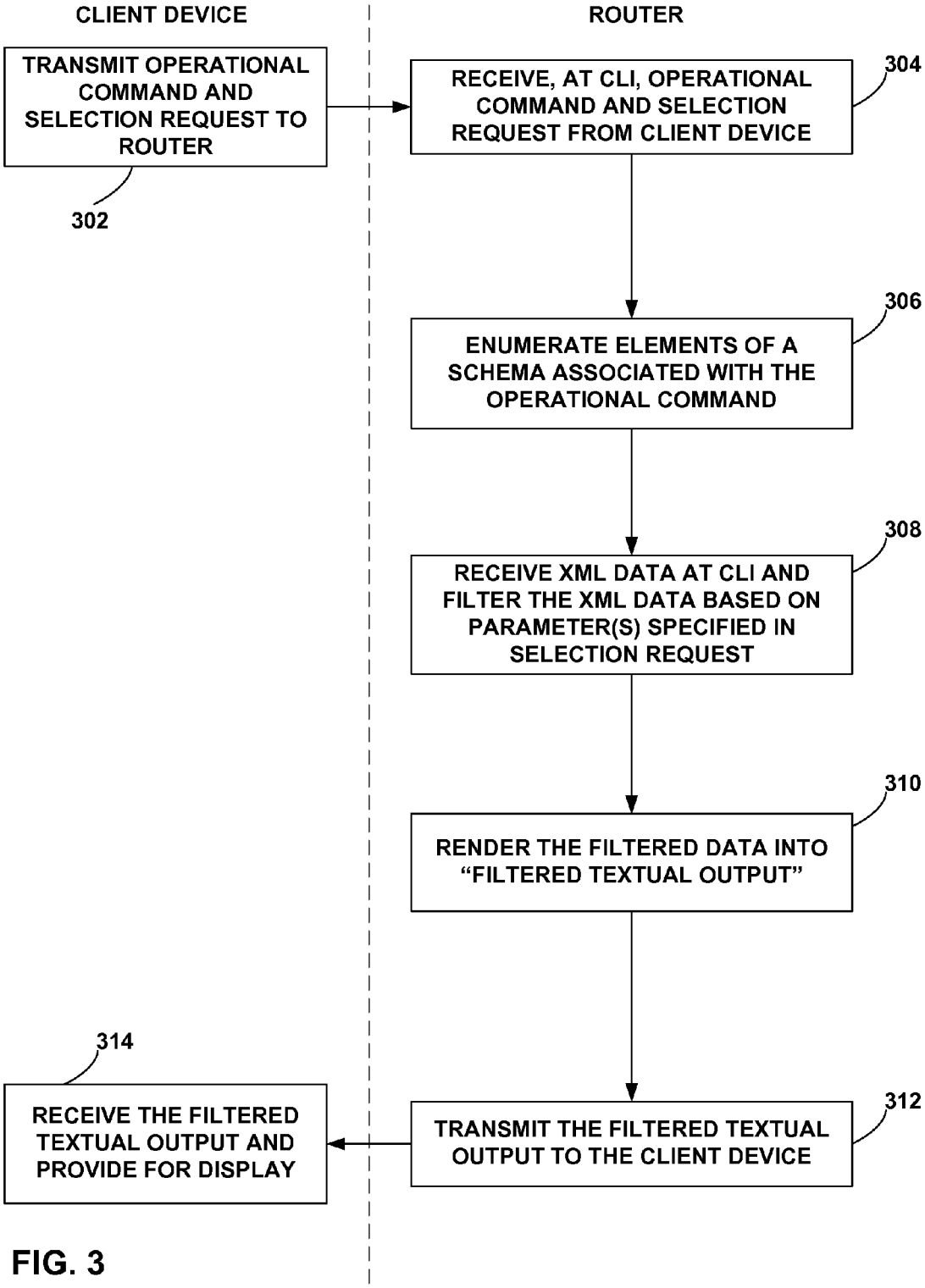
CLIENT DEVICE
ROUTER
TRANSMIT OPERATIONAL COMMAND AND SELECTION REQUEST TO ROUTER
302
RECEIVE, AT CLI, OPERATIONAL COMMAND AND SELECTION REQUEST FROM CLIENT DEVICE
304
ENUMERATE ELEMENTS OF A SCHEMA ASSOCIATED WITH THE OPERATIONAL COMMAND
306
RECEIVE XML DATA AT CLI AND FILTER THE XML DATA BASED ON PARAMETER(S) SPECIFIED IN SELECTION REQUEST
308
RENDER THE FILTERED DATA INTO "FILTERED TEXTUAL OUTPUT"
310
TRANSMIT THE FILTERED TEXTUAL OUTPUT TO THE CLIENT DEVICE
312
RECEIVE THE FILTERED TEXTUAL OUTPUT AND PROVIDE FOR DISPLAY
314

FIG. 3

FILTERING OUTPUT FROM OPERATIONAL COMMANDS EXECUTED ON A NETWORK DEVICE

TECHNICAL FIELD

The present disclosure relates to computer networks, and, more specifically, to user interfaces for devices within computer networks.

BACKGROUND

A computer network is a collection of interconnected computing devices that exchange data and share resources. Examples of network devices include routers, switches, firewalls, VPN appliances and security devices.

Administrators configure, manage, and otherwise interact with network devices to ensure and monitor network operation. For example, an administrator may interact with a router via a client device (e.g., a management device) to set various configuration parameters and to collect and view current settings and statistics. In many cases, a router will output rich and voluminous data to a requesting client device, thus providing a complete response to the request.

Network devices in general, and routers in particular, are becoming more and more powerful and versatile in terms of their performance and capabilities. In turn, these network devices are gaining complexity in their architecture, operation, and functionality. As a result, tasks such as configuring and managing these network devices are also becoming more complex and intricate.

SUMMARY

In general, techniques of the present disclosure enable a user to selectively view data that a router outputs in response to an operational command. More specifically, techniques of the present disclosure provide a schema enumeration module that classifies data in an extensible markup language (e.g., "XML") into distinct portions in accordance with an XML schema that defines the data. More specifically, the schema enumeration module assigns a unique element number to each element of the defining XML schema. The schema enumeration module then correlates portions of the XML data to unique element numbers in the enumerated schema. By correlating portions of the XML data to the unique element numbers of the enumerated schema, the schema enumeration module enables automatic filtering of the XML data based on the enumeration.

Techniques further provide a filtering module that enables a user to filter the XML data by mapping a user-specified field identifier to a unique element number of the enumerated schema, and modifying the textual output accordingly. The filtering module accepts a selection request that specifies criteria by which to filter the XML data. For example, a selection request may specify parameters by which to either include certain portions of the XML data, or exclude certain portions. The selection request specifies a portion of the XML data by specifying a field identifier that corresponds with a unique element number of the enumerated schema. Since each portion of the XML data is correlated to a unique element number of the enumerated schema, the field identifier is sufficient for the filtering module to identify a portion of the XML data. Based on the parameters specified in the selection request, the filtering module selects portions of the XML data to form filtered XML data.

Techniques further provide a rendering module that converts the filtered XML data into a textual format that is intelligible to a user. The rendering module thus generates "filtered textual output" that is in a format that a user can comprehend, and includes data that is both responsive to the operational command and conformant to the selection request. The router then transmits the filtered textual output to the client device. Thus, by utilizing the techniques described in the present disclosure, a user can "selectively view" specific portions of the textual output.

In one example, a method in accordance with one or more aspects of the present disclosure includes receiving, at an interface of a network router, an input from a client device using a communicative connection, wherein the input comprises an operational command and a selection request, and wherein the selection request specifies a field identifier. The method also includes enumerating a schema identified by the operational command to form an enumerated schema, wherein the schema defines a class of elements that conform to a data description language, and wherein the enumerating includes assigning a unique element number to each element of the defined class of elements. The method further includes receiving, at the interface, data generated based at least in part on the schema, wherein the received data conforms to the data description language, and filtering the received data to form filtered data, wherein the filtering includes mapping the field identifier specified by the selection request to a unique element number of the enumerated schema. The method further includes rendering the filtered data to form a filtered textual output comprising one or more fields, wherein each field is associated with a unique element number of the enumerated schema, and transmitting, from the interface, the filtered textual output to the client device using the communicative connection.

In another example, a routing device in accordance with one or more aspects of the present disclosure includes a network interface that receives an input from a client device using a communicative connection, wherein the input comprises an operational command and a selection request, and wherein the selection request specifies a field identifier. The routing device also includes a schema enumeration module that enumerates a schema identified by the operational command to form an enumerated schema, wherein the schema defines a class of elements that conform to a data description language, and wherein the schema enumeration module enumerates the schema at least in part by assigning a unique element number to each element of the defined class of elements. The routing device also includes an interface that receives data generated based at least in part on the schema, wherein the received data conforms to the data description language, and a filtering module that filters the received data to form a filtered data, wherein the filtering module filters the received data at least in part by mapping the field identifier specified by the selection request to a unique element number of the enumerated schema. The routing device also includes a rendering module of the schema enumeration module that renders the filtered data to form a filtered textual output comprising one or more fields, wherein each field is associated with a unique element number of the enumerated schema. The routing device also includes a transmission module of the network interface that transmits the textual output from the interface to the client device using the communicative connection.

In another example, a computer-readable medium includes instructions for causing a programmable processor of a routing device to receive, at an interface of the routing device, an input from a client device using a communicative connection,

wherein the input comprises an operational command and a selection request, and wherein the selection request specifies a field identifier. The computer-readable medium also includes instructions for causing a programmable processor of the routing device to enumerate a schema identified by the operational command to form an enumerated schema, wherein the schema defines a class of elements that conform to a data description language, and wherein the enumerating includes assigning a unique element number to each element of the defined class of elements. The computer-readable medium also includes instructions for causing a programmable processor of the routing device to receive, at the interface, data generated based at least in part on the schema, wherein the received data conforms to the data description language, filter the received data to form filtered data, wherein the filtering includes mapping the field identifier specified by the selection request to a unique element number of the enumerated schema, and render the filtered data to form a filtered textual output comprising one or more fields, wherein each field is associated with a unique element number of the enumerated schema. The computer-readable medium also includes instructions for causing a programmable processor of the routing device to transmit, from the interface, the filtered textual output to the client device using the communicative connection.

In another example, a method includes receiving, at a user interface (UI) of a client device, an input comprising an operational command and a selection request, wherein the selection request specifies a field identifier and one or more parameters. The method also includes transmitting, from a network interface of the client device, the input to a routing device using a communicative connection, and receiving, at the network interface, a filtered textual output from the routing device, wherein the filtered textual output forms at least a portion of a textual output solicited by the operational command, and wherein the filtered textual output conforms to the one or more parameters specified by the selection request. The method also includes providing the filtered textual output for display at the UI of the client device.

In another example, a client device includes a user interface (UI) that receives an input comprising an operational command and a selection request, wherein the selection request specifies a field identifier and one or more parameters. The client device also includes a network interface that transmits the input to a routing device using a communicative connection, and receives a filtered textual output from the routing device, wherein the filtered textual output forms at least a portion of a textual output solicited by the operational command, and wherein the filtered textual output conforms to the one or more parameters specified by the selection request. The client device also includes a display device that provides the filtered textual output for display at the UI.

The techniques described herein may provide certain advantages. For example, the techniques provide generic mechanisms that allow a user to define a specific search query or output filter for any command supported by a schema-driven interface of a network device in accordance with aspects of the present disclosure. These generic mechanisms are scalable in that they may be applied without change (or "on-box") to any command supported by future versions of the schema-driven interface. As another example, the techniques provide an elegant mechanism by which a user is able to easily reduce the amounts of output to locate information that is relevant to the user. By including a selection request in an input, the user is able to utilize the filtering module to request that only certain data be displayed. Conversely, the user can specify certain data (or families of data) that the user wishes to be excluded from the output. As a result, the user can view data pertinent to the user's request, and avoid viewing unnecessary data that is otherwise associated with the pertinent data. As another example, the techniques described herein may reduce the amount of data transmitted over the network. The selection request is implemented by the router, i.e. the router filters the output before transmitting to the client device. Since the router transmits filtered output to the client device, techniques of the present disclosure enable more efficient use of network bandwidth and resources.

The details of one or more examples of the disclosure are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the disclosure will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a block diagram illustrating an example network router that incorporates a routing engine in accordance with one or more aspects of the present disclosure.

FIG. **2** is a block diagram illustrating an example routing engine of a network router, in accordance with one or more aspects of the present disclosure.

FIG. **3** flow chart illustrating an example process by which a router participates in a communicative session with a client device, in accordance with one or more aspects of the present disclosure.

DETAILED DESCRIPTION

FIG. **1** is a block diagram illustrating an example network router **100** that includes routing engine **102** and forwarding engine **116**, in accordance with one or more aspects of the present disclosure. In the example of FIG. **1**, routing engine **102** executes software that provides a command line interface (CLI) **104**. CLI **104** is one non-limiting example of an interface provided by the techniques of the present disclosure. In addition, routing engine **102** includes an operating system **120** that provides an operating environment for executing one or more other control processes. Examples of such processes include management server module **110** and software modules **112**A-**112**N ("software modules **112**"). Some non-limiting examples of software modules **112** include a chassis module, a device configuration module, a routing protocol module, an event management module, and a simple network management protocol (SNMP) module, to name a few.

CLI **104** facilitates communication between network router **100** and client device **118** and supports a command syntax that allows client device **118** to configure the operation of the network router as well as view current operational settings and statistics. Client device **118** may be a standalone computer executing a web browser or other client-side software component or a network management system executing a sophisticated configuration tool. Network router **100** and client device **118** may communicate using one of several network protocols. Examples of such communication protocols include telnet and secure shell (SSH) or SNMP. Further details of example communications between a network management system and a managed device, such as a router, may be found in U.S. patent application Ser. No. 12/688,635, "DYNAMIC OPTIMIZATION OF DEVICE MANAGEMENT COMMAND FOR BULK RETRIEVAL OF CONFIGURATION DATA," incorporated herein by reference.

In some examples, CLI **104** receives operational commands entered by a user via client device **118**. In other examples, CLI **104** receives operational commands issued by

a script or other management software executed by client device **118**. In either case, the operational commands supported by the command syntax of CLI **104** may be capable of producing significant output data. For example, CLI **104** may support a command such as a "SHOW" command, for viewing current physical components and configuration parameters of network router **100**. In cases where router **100** is a high-end network router, such as a core router, the resultant output produced by execution of the operational command may be significant. Further details of example structures for implementing operational commands within a device, such as a router, can be found in U.S. patent application Ser. No. 10/339,719, "GENERATION OF A CONFIGURATION PATCH FOR NETWORK DEVICES," incorporated herein by reference.

As described herein, CLI **104** provides generic mechanisms that allow client device **118** to narrowly tailor the execution of virtually any operational command supported by the CLI. For example, as further described below, the generic mechanisms allow client device **118** to more specify particular queries or output filters for any operational command supported by the command syntax. The generic mechanisms may be used with any command without requiring modification to the syntax and semantics for the specific command. Moreover, the mechanisms are extensible and scalable in that they are implemented by CLI **104** in a manner that allow the mechanisms to automatically be applied by the CLI as new commands are supported by future versions of the command syntax.

In the example of FIG. **1**, CLI **104** receives input specifying one or more operational commands and forwards the operational commands to management server module **110**. Management server module **110** processes the input and directs the operational commands to the appropriate software modules **112** for execution. Management server module **110** then receives any output data from software modules **112** from execution of the commands, and forwards the data to CLI **104**. Network router **100** produces the output data in a form that conforms to a data description language, such as the extensible markup language ("XML"), and in a structure that is defined by one or more schemas.

Devices that support data description languages, such as XML, often employ one or more schemas to define XML data generated by the device. More specifically, an XML schema specifies schema components to define the meaning, usage, and relationships of elements within the generated XML data. An XML schema may be described using one of several XML schema definition languages, such as "XML Schema" published by the World Wide Web Consortium (W3C), Document Content Description for XML (DCD), DOCUMENT Definition Markup Language (DDML), Regular Language for XML Next Generation (RELAX NG), Schema for Object-Oriented XML (SOX), and Document Structure Description (DSD), among others. Example of schema-driven configuration interface for a device, such as a router, can be found in U.S. patent application Ser. No. 12/510,062, "MERGING NETWORK DEVICE CONFIGURATION SCHEMAS," incorporated herein by reference. XML schemas and corresponding validation procedures are described in greater detail by W3C, XML Schema Part 0: Primer (Oct. 28, 2004, Second Edition, editors David C. Fallside and Priscilla Walmsley); W3C, XML Schema Part 1: Structures Second Edition (Oct. 28, 2004, Second Edition, editors Henry S. Thompson et al.); and W3C, XML Schema Part 2: Datatypes (Oct. 28, 2004, Second Edition, editors Paul V. Biron and Ashok Malhotra), which are each incorporated by reference herein in their respective entireties.

As shown in FIG. **1**, CLI **104** includes output definition language (ODL) module **106** and output query module **108** that operate to provide generic mechanisms that allow client device **118** to define a specific search query or output filter for any operational command supported by the CLI. Client device **118** may avail of these generic mechanisms by sending CLI **202** a user input that includes both an operational command and a selection request. For example, after CLI **104** receives data from management server module **110**, ODL module **106** and output query module **108** operate collaboratively to filter and convert (or "render") the received data into a filtered textual output. In one example, ODL module **106** and output query module **108** filter and render the data into filtered textual output by using a four-step process. First, ODL module **106** identifies the particular module of software modules **112** that generated the data. Second, output query module **108** enumerates an XML schema associated with the identified module by assigning a unique element number to each element specified within the XML schema. Third, output query module **108** filters the received data based on the selection request included in the user input. Fourth, ODL module **106** converts the filtered data to textual format, and arranges the filtered textual data to make the filtered textual data intelligible to a user. Example arrangements include tabular, hierarchical, and numbered list arrangements. In some examples, ODL module **106** arranges the textual data by correlating various fields in the textual data with enumerated elements of the schema from which the textual data was generated. In some examples, the operational command includes a "show interfaces" command. In these examples, the corresponding XML schema may include elements such as an interface name, administrator status, and logical interface, among others. The XML schema may further include the name, administrator status, etc. of the logical interface element. In one such example, ODL module **106** generates textual output arranged in a tabular fashion. In this example, the table includes field headings corresponding to elements of the XML schema from which the textual output was generated.

In this manner, the command syntax supported by CLI **104** has been enhanced with a generic mechanism that allows client device **118** to include a selection request when issuing any of the commands supported by the router. For any given command supported by CLI **104**, a selection request may be used to specify a particular search query or output filter relative to the enumeration of the schema defining the elements of the output data produced by execution of the command. Moreover, as described in further detail below, CLI **104** has been enhanced to allow a user to easily view the enumeration of the schema associated with the output data for any operational command, thereby allowing the user to easily construct selection requests when issuing operational commands to network router **100**. Although described for exemplary purposes with respect to router **100**, the techniques may be applied to any managed device.

FIG. **2** is a block diagram illustrating an example routing engine **200** of a network router, in accordance with one or more aspects of the present disclosure. Routing engine **200** is one non-limiting example of routing engine **102** illustrated in FIG. **1**. As shown in FIG. **2**, routing engine **200** includes command line interface (CLI) **202**, management module **208**, chassis module **212**, device control module **216**, and routing protocol module **220**. Chassis module **212**, device control module **216**, and routing protocol module **220** are three non-limiting examples of software modules **112** illustrated in FIG. **1**. CLI **202** further includes output query module **204** and output definition language (ODL) module **206**. Output query

module **204** and ODL module **206** are non-limiting examples of a filtering module and a schema enumeration module, respectively. Management module **208** further includes an XML schema, namely, configuration schema **210**. Similarly, chassis module **212** includes chassis schema **214**, device control module **216** includes device control schema **218**, and routing process module **220** includes routing process schema **222**.

CLI **202** is one non-limiting example of CLI **104** of FIG. **1**. As discussed with respect to FIG. **1**, CLI **202** is capable of receiving user input that includes both an operational command and a selection request. After CLI **202** receives a user input including an operational command and a selection request, CLI **202** forwards the operational command to management module **208**. Management module **208** utilizes configuration schema **210** to identify a software module that includes an XML schema associated with the operational command. Management module **208** then forwards the operational command to the identified software module. In the specific example of FIG. **2**, management module **208** may forward an operational command to one or more of chassis module **212**, device control module **216**, and routing protocol module **220**. The particular software module that received the operational command then generates XML data (defined by the software module's XML schema) responsive to the operational command, and sends the XML data to management module **208**.

In one example, CLI **202** receives an operational command that solicits information pertaining to a routing process implemented by routing engine **200**. In this example, management module **208** utilizes configuration schema **210** to determine that routing process module **220** includes the appropriate XML schema (namely, routing process schema **222**) to respond to the operational command. Management module **208** then sends the operational command to routing process module **220**, and routing process module **220** generates XML data responsive to the operational command. Routing process module **220** utilizes routing process schema **222** to define the generated XML data. Routing process module **220** sends the generated XML data to management module **208**. Management module **208** then forwards the received XML data to CLI **202**.

In this and other examples, CLI **202** receives XML data sent from management module **208**, and utilizes output query module **204** to filter the XML data according to a user input. In the example illustrated in FIG. **2**, CLI **202** receives a user input that includes a selection request. As discussed, CLI **202** receives the selection request concurrently with an operational command included in a user input. In some examples, the selection request specifies one or more elements of the schema from which the XML data was generated, and uses the specified element(s) to define one or more parameters by which to filter the XML data. CLI **202** utilizes output query module **204** to apply the parameter(s) of the selection request to the XML data, thus generating filtered XML data. In some examples, output query module **204** may filter the received XML data by using a two-step process. First, output query module **204** enumerates an XML schema (in this case, routing process schema **222**) by assigning a unique element number to each element of the XML schema. Second, output query module maps the element(s) specified in the selection request to the element numbers of the XML schema, and applies the parameters of the selection request to filter the received XML data accordingly.

An example of an operational command is a "show interfaces" operational command. As discussed, management module **208** forwards the "show interfaces" operational command to the appropriate software module (e.g., routing process module **220**). In some examples, CLI **202** also receives, concurrently with the "show interfaces" operational command, a selection request to filter the output transmitted in response to the "show interfaces" operational command. In one such example, the selection request defines a parameter associated with an "administrator status" element of routing process schema **222**. More specifically, the selection request defines a parameter that states that the resulting output only include data such that the "administrator status" field includes a value of "down." In this example, output query module **204** applies the selection request to filter out all portions of the XML data that include "administrator status" fields with values other than "down."

In the example illustrated in FIG. **2**, output query module **204** sends the filtered XML data to ODL module **206**. In some examples, ODL module **206** is itself an XML schema that defines XML data that CLI **202** can generate. In these and other examples, ODL module stores so-called "metadata" associated with one or more software modules and/or the software modules' respective XML schemas (e.g., chassis module **212** and/or chassis schema **214**). In other examples, ODL module **206** includes an XML schema known as a definition schema. In these examples, ODL module **206** utilizes the definition schema to define XML data that CLI **202** can generate.

ODL module **206** defines one or more rules **224** for rendering the filtered XML data received from output query module **204** into textual format, forming "filtered textual output." Examples of rules **224** include formatting and rendering rules, among others. In some examples, ODL module **206** defines rules **224** to include one or more formatting rules by which to arrange fields of the filtered textual output (e.g., whether to arrange the textual output in tabular, hierarchical, or numbered list formats, among others). After receiving the filtered XML data from output query module **204**, ODL module **206** applies rules **224** to convert the filtered XML data into filtered textual output. CLI **202** then sends the filtered textual output to the client device that forwarded the user input including the operational command and the selection request.

FIG. **3** is a flowchart illustrating an example process by which a router participates in a communicative session with a client device, in accordance with one or more aspects of the present disclosure. For purposes of illustration only, FIG. **3** will be described with respect to the devices of FIGS. **1-2**. In the example of FIG. **3**, client device **118** transmits a user input to a router, such as router **100** (**302**). In one example, the user input includes both an operational command and a selection request. Router **100** then receives the transmitted input at a command line interface, such as CLI **104** (**304**). In one example, router **100** responds to the operational command of the user input by executing a number of steps. First, router **100** identifies an XML schema (e.g., routing process schema **222**) that corresponds to the operational command. In many instances, one of software modules **112** running on router **100** includes the identified XML schema (e.g., routing process module **220** includes routing process schema **222**). In these instances, router **100** forwards the operational command to the particular module of software modules **112** that includes the identified XML schema. Responsive to the operational command, the software module generates XML data that conforms to the schema. In some examples, device control module **216** generates XML data (e.g., an XML document) that includes one or more fields defined by elements of device control schema **218**. Device control module **216** then sends the generated XML data to CLI **202**. In one such example, device control module **216** sends the XML data to a central

software module, such as management module **208**, and management module **208** forwards the XML data to CLI **202**. In some examples, software modules **112** device may also be termed as "daemons" or "processes" running on an operating system of the router.

Router **100** then enumerates the schema identified with the operational command (**306**). The router may enumerate the schema using an output query module, e.g., output query module **204** of routing engine **200**. In some examples, the output query module is a part of the CLI (e.g., output query module **204** of CLI **202**). In other examples, the output query module is external to the CLI, but is communicatively coupled to the CLI. ODL module **206** also includes an XML schema, namely, definition schema **226**. In some examples, definition schema **206** includes elements that indicate what types of information may be emitted by software modules **112** of router **100**. In some examples, definition schema **226** includes elements that indicate the types of information that chassis schema **214** can emit. In one such example, definition schema **226** includes elements associated with elements of chassis schema **214**. In this example, since chassis module **212** generates and emits XML data defined by chassis schema **214**, definition schema **226** includes indications of the types of data that chassis module **212** may emit.

In some examples, router **100** enumerates the identified XML schema by assigning a unique element number to each element of the identified XML schema. For example, routing process schema **222** includes elements corresponding to one or more interfaces of client devices communicatively connected to the router. Example elements of routing process schema **222** include a name, administrator status, and logical interface associated with each interface. In one such example, router **100** assigns a unique element number to each of the name, the administrator status, and the logical interface elements of routing process schema **222**.

Router **100** then filters the XML data received in response to the operational command based on one or more parameters defined in a selection request of the user input (**308**). In some examples, router **100** utilizes an output query module (e.g., output query module **108** or output query module **204**) to filter the XML data. In some examples, the parameter(s) are based on one or more elements of the corresponding XML schema (in this case, routing process schema **222**). As discussed, a user input may include both an operational command and a selection request.

Router **100** then renders the filtered XML data into a textual format (**310**). The resulting output may be known as "filtered textual output." In one example, to render the filtered XML data into filtered textual output, router **100** utilizes ODL module **106** to convert the filtered XML data into text that is intelligible to a user. Additionally, router **100** may arrange the filtered textual output in a tabular fashion (e.g., using elements of the corresponding XML schema as field headings), or in a hierarchical fashion (e.g., based on a hierarchy of the corresponding schema), among other examples. An example of an operational command (without an accompanying selection request) and its corresponding output in a tabulated textual format is presented below:

```
regress@bng-ui-vm-09> show interfaces terse
Interface   Admin   Link   Proto   Local
em0.0       up      up     inet    10.209.3.211/18
```

In the example presented, the user input includes a "show interfaces" operational command. For purposes of illustration only, the example output includes data associated with a single interface. Router **100** arranges the textual output in a tabulated fashion to include a list of field headings. In this example, the field headings include an interface name ("interface"), administrator status ("admin"), link status ("link"), address family name ("proto"), and address ("local"). As discussed, these field headings correspond to elements of an XML schema, e.g. routing process schema **222**.

As discussed, router **100** generates the textual output from XML data generated by a software module of router **100** (e.g., routing process module **220**). The XML data corresponding to the textual output illustrated above appears as follows:

```
<physical-interface>
  <name>em0</name>
  <admin-status>up</admin-status>
  <oper-status>up</oper-status>
  <logical-interface>
    <name>em0.0</name>
    <admin-status>up</admin-status>
    <oper-status>up</oper-status>
    <address-family>
      <address-family-name>inet</address-family-name>
      <interface-address>
        <ifa-local>10.209.3.211/18</ifa-local>
      </interface-address>
    </address-family>
  </logical-interface>
</physical-interface>
```

As discussed, a user input may include both an operational command and a selection request. Two examples of user input and corresponding output are presented below. The first example user input includes only an operational command, and appears as follows:

```
regress@bng-ui-vm-09>  show interfaces terse
Interface     Admin     Link     Proto     Local
cbp0          up        up
demux0        up        up
dsc           down      up
em0           up        up
em0.0         up        up       inet      10.209.3.211/18
gre           up        up
ipip          up        up
irb           up        up
lo0           up        up
lo0.0         up        up       inet      127.0.0.1
lo0.16384     up        up       inet      127.0.0.1
lo0.16385     down      up       inet      128.0.0.4
lo0.32768     up        up
lsi           up        up
mtun          up        up
pimd          up        up
pime          up        up
pip0          down      down
pp0           up        up
tap           up        up
```

As shown, the user input includes a "show interfaces" operational command. In this example, the textual output corresponding to the "show interfaces" operational command includes data associated with 20 interfaces (illustrated by the presence of 20 rows, apart from the row of field headings). The textual output is arranged in a tabular format, and includes the same field headings as the output illustrated in the previous example.

A second example of a user input includes both an operational command as well as a selection request. In this example, the user may first utilize a "context-sensitive help" to view an enumerated representation of attributes of an XML schema associated with the operational command. An

example use of context-sensitive help associated with the "show interfaces" operational command appears as follows:

```
regress@bng-ui-vm-09> show interfaces terse | filter select-query ?
 1              physical-interface
 2                name
 3                admin-status
 4                oper-status
 5                logical-interface
 6                  name
 7                  admin-status
 8                  oper-status
 9                  address-family
10                    address-family-name
11                    interface-address
12                    ifa-local
```

The illustrated context-sensitive help command includes an operational command ("show interfaces") and an enumeration request ("filter select-query ?"). As illustrated, the output responsive to the context-sensitive help includes a list of fields, and each field is associated with a unique field number. For example, field number "10" is associated with an "address family name" field of a logical interface. In some examples, each field is associated with an attribute of an XML schema associated with the operational command. In the example illustrated above, an XML schema identified by the "show interfaces" operational command includes elements associated with an interface name, administrator status, operational status, and logical interface. The schema further includes elements associated with the logical interface, such as an address family. The schema further includes elements associated with the address family (e.g., an interface address). As shown, the textual output includes fields arranged in a hierarchical format. More specifically, fields that represent elements associated with the logical interface are indented further than fields that represent elements associated directly with the physical interface. Similarly, fields that represent attributes associated with the address family of the logical interface are indented further still.

Based on the enumerated schema displayed in response to the context-sensitive help command, a user may formulate a selection request to include in the user input. In some examples, a user adds a selection request to the discussed example of a "show interfaces" operational command. For example, a user may wish to selectively view those portions of the output that include a "down" value associated with an administrator status element. As shown in the above example, the output includes two fields associated with an administrator status element described in the schema. The first such field is associated with a physical interface element, and the second such field is associated with a logical interface element.

To selectively view portions of the output that include a "down" value associated with administrator status, a user may include a selection request that specifies the unique field numbers associated with the administrator status attributes of the schema. As shown in the context-sensitive help output illustrated, fields representing the administrator status elements are associated with field numbers "3" and "7." An example user input that includes the "show interfaces" operational command and a selection request that utilizes field identifiers associated with the administrator status elements is illustrated below.

```
regress@bng-ui-vm-09> show interfaces terse | filter select-query
($3 == "down" | | $7 == "down")
```

-continued

Interface	Admin	Link	Proto	Local
dsc	down	up		
lo0.16385	down	up	inet	128.0.0.4
pip0	down	down		

In the example illustrated, the selection request specifies two field identifiers, namely, field identifiers "$3" and "$7" associated with field numbers **3** and **7**, respectively. The selection request solicits output that includes a "down" value associated with either field number "3" or field number "7" as indicated in the context-sensitive help. As discussed, each field listed in the context-sensitive help is associated with an attribute of an XML schema that defines the output. In the illustrated example, field identifiers "$3" and "$7" specify the administrator status of a physical interface, and administrator status of a logical interface, respectively.

The corresponding output includes data associated with three interfaces. As shown in the illustrated output, each interface includes a "down" value in at least one of the specified fields. More specifically, the first two interfaces include a "down" value associated with the administrator status of the physical interface, and the third interface includes a "down" value associated with both an administrator status of the physical interface as well an administrator status of the logical interface.

The selection request of the illustrated example filters the output by specifying a field identifier(s), and a value(s) that should be included in fields identified by the field identifier. In other examples, the selection request specifies values to be omitted from the output. One such example of a selection request appears as follows:

regress@bng-ui-vm-09> show interfaces terse | filter select-query ($3 !="down" | $7 !="down")

In this example, the selection request specifies the same field identifiers (namely, fields associated with field numbers "3" and "7" of the context-sensitive help). Router **100** applies the selection request to filter the output to include only those portions that include a value other than "down" for both the administrator status of the physical interface and the administrator status of the logical interface.

As shown in the above examples, a selection request may use Boolean operators to define parameters. For example, to solicit an output that includes a "down" value associated with field number "3," the selection request includes an expression that reads as follows:

$3 == "down"

Similarly, to solicit an output that includes a "down" value associated with either field number "3" or field identifier "7," the selection request includes an expression that appears as follows:

$3 == "down" || $7 == "down"

Both examples include well-known Boolean operators, such as "||" to signify an "or" operation.

In the examples described, each selection request specifies one or more field identifiers, and specifies one or more values to either include or exclude from the filtered output. These examples illustrate examples of selection requests that are termed as "select query" selection requests.

In other examples, a selection request specifies one or more field identifiers, and filters the output by either including or excluding all data associated with the identified field(s). These examples illustrate selection requests that are termed as "select field" requests. An example of a user input that applies a "select field" selection request to the "show interfaces" operational command is illustrated below.

regress@bng-ui-vm-09> show interfaces terse | filter select-field exclude $10

Interface	Admin	Link	Local
cbp0	up	up	
demux0	up	up	
dsc	down	up	
em0	up	up	
em0.0	up	up	10.209.3.211/18
gre	up	up	
ipip	up	up	
irb	up	up	
lo0	up	up	
lo0.0	up	up	127.0.0.1
lo0.16384	up	up	127.0.0.1
lo0.16385	down	up	128.0.0.4
lo0.32768	up	up	
lsi	up	up	
mtun	up	up	
pimd	up	up	
pime	up	up	
pip0	down	down	
pp0	up	up	
tap	up	up	

In this example, the field heading identified by field identifier "$10" is excluded from the output. More specifically, field identifier "$10" identifies a field associated with field number "10" as shown in the context-sensitive help output. Field number "10" is associated with an "address family name" attribute of the XML schema corresponding to the "show interfaces" operational command. In this example, the filtered output does not include the field heading "proto," associated with the address family name attribute. The filtered output also does not include any data associated with the address family name attribute.

Similarly, the "select field" selection request may specify one or more field identifiers in order to include data in the filtered output. For example, a user input that includes a "show interfaces" command and a "select field" selection request may appear as follows:

regress@bng-ui-vm-09> show interfaces terse | filter select-field include $5

In this example, the "select field" selection request filters the output to only include data associated with field number "5" referenced in the context-sensitive help. More specifically, the illustrated user input will solicit output that includes data defined by the "logical interface" element of the XML schema identified by the "show interfaces" operational command. However, the solicited output will not include data associated with other field numbers of the context-sensitive help (e.g., field number "2," which identifies a "name" element that is directly associated with the physical interface).

By applying the selection request to the output generated in response to the operational command, router **100** generates a "filtered textual output." Next, router **100** transmits the filtered textual output to client device **118** using the communicative connection (**312**). In many examples, the filtered textual output includes a significantly reduced quantity of data than the textual output before filtering. Due to the significant reduction in data quantity, router **100** more efficiently uses the communicative connection (e.g., consuming less network bandwidth) when transmitting the filtered textual output to client device **118**.

Client device **118** then receives the filtered textual output and provides the filtered textual output for display (**314**). Since the user specified the selection request (**302**), the filtered textual output matches parameters of the user's choosing. By displaying the filtered textual output, client device **118** enables the user to selectively view the textual output generated in response to the operational command. Since the user selectively views the textual output, the user need not sort through unwanted information before locating the information the user wishes to view. In many examples, the filtered textual output is limited to information that the user specified using the selection request.

Various examples have been described. These and other examples are within the scope of the following claims.

What is claimed is:

1. A method comprising:

receiving, at an interface of a routing device, an input from a client device using a communicative connection, wherein the input comprises an operational command and a selection request, and wherein the selection request specifies a field identifier;

enumerating a schema identified by the operational command to form an enumerated schema, wherein the schema defines a class of elements that conform to a data description language, and wherein the enumerating includes assigning a unique element number to each element of the defined class of elements;

receiving, at the interface, data generated based at least in part on the schema, wherein the received data conforms to the data description language;

filtering the received data to form filtered data, wherein the filtering includes mapping the field identifier specified by the selection request to a unique element number of the enumerated schema;

rendering the filtered data to form a filtered textual output comprising one or more fields, wherein each field is associated with a unique element number of the enumerated schema; and

transmitting, from the interface, the filtered textual output to the client device using the communicative connection.

2. The method of claim **1**, wherein the interface comprises a command line interface (CLI).

3. The method of claim **1**, wherein the data description language is an extensible markup language (XML).

4. The method of claim **1**, wherein the filtering comprises omitting a portion of the received data that is associated with the unique element number mapped to field identifier.

5. The method of claim **1**, wherein the filtering comprises omitting one or more portions of the received data that are different from the portion associated with the unique element number mapped to field identifier.

6. The method of claim **1**, wherein the selection request further specifies a data value.

7. The method of claim **6**, wherein the filtering comprises omitting a portion of the received data that includes the specified data value.

8. The method of claim **6**, wherein the filtering comprises omitting a portion of the received data that includes a second data value different from the specified data value.

9. A routing device comprising:

a network interface that receives an input from a client device using a communicative connection, wherein the input comprises an operational command and a selection request, and wherein the selection request specifies a field identifier;

a schema enumeration module that enumerates a schema identified by the operational command to form an enumerated schema, wherein the schema defines a class of elements that conform to a data description language, and wherein the schema enumeration module enumerates the schema at least in part by assigning a unique element number to each element of the defined class of elements;

an interface that receives data generated based at least in part on the schema, wherein the received data conforms to the data description language;

a filtering module that filters the received data to form filtered data, wherein the filtering module filters the received data at least in part by mapping the field identifier specified by the selection request to a unique element number of the enumerated schema;

a rendering module of the schema enumeration module that renders the filtered data to form a filtered textual output comprising one or more fields, wherein each field is associated with a unique element number of the enumerated schema;

and

a transmission module of the network interface that transmits the filtered textual output from the interface to the client device using the communicative connection.

10. The routing device of claim **9**, wherein the filtering module filters the received data at least in part by omitting a portion of the received data that is associated with the unique element number mapped to the field identifier.

11. The routing device of claim **9**, wherein the filtering module filters the received data at least in part by omitting one or more portions of the received data that are different from the portion associated with the unique element number mapped to field identifier.

12. The routing device of claim **9**, wherein the selection request further specifies a data value.

13. The routing device of claim **12**, wherein the filtering module filters the received data at least in part by omitting a portion of the received data that includes the specified data value.

14. The routing device of claim **12**, wherein the filtering module filters the received data at least in part by omitting a portion of the received data that includes a second data value different from the specified data value.

15. A non-transitory computer-readable medium comprising instructions for causing a programmable processor of a routing device to:

receive, at an interface of the routing device, an input from a client device using a communicative connection, wherein the input comprises an operational command and a selection request, and wherein the selection request specifies a field identifier;

enumerate a schema identified by the operational command to form an enumerated schema, wherein the schema defines a class of elements that conform to a data description language, and wherein the enumerating includes assigning a unique element number to each element of the defined class of elements;

receive, at the interface, data generated based at least in part on the schema, wherein the received data conforms to the data description language;

filter the received data to form filtered data, wherein the filtering includes mapping the field identifier specified by the selection request to a unique element number of the enumerated schema;

render the filtered data to form a filtered textual output comprising one or more fields, wherein each field is associated with a unique element number of the enumerated schema; and

transmit, from the interface, the filtered textual output to the client device using the communicative connection.

16. A method comprising:

receiving, at a user interface (UI) of a client device, an input comprising an operational command and a selection request, wherein the selection request specifies a field identifier and one or more parameters, and wherein the field identifier maps to a unique element number of an enumeration of a schema identified by the operational command, wherein the schema defines a class of elements that conform to a data description language and controls output of configuration information by a network device, and wherein the enumeration of the schema assigns a unique element number to each element of the defined class of elements;

transmitting, from a network interface of the client device, the input to the network device, using a communicative connection;

receiving, at the network interface, a filtered textual output from the network device, wherein the filtered textual output forms at least a portion of a textual output solicited by the operational command, and wherein the filtered textual output comprises one or more fields, wherein each field is associated with a unique element number of the enumeration of the schema, and wherein the filtered textual output is filtered based on the mapping of the field identifier to the enumeration of the schema and conforms to the one or parameters specified by the selection request; and

providing the filtered textual output for display at the UI of the client device.

17. The method of claim **16**, wherein a parameter of the one or more parameters requests omission from the filtered textual output a field of the textual output, and wherein the field is associated with the field identifier.

18. The method of claim **16**, wherein a parameter of the one or more parameters requests inclusion in the filtered textual output a field of the textual output, and wherein the field is associated with the field identifier.

19. The method of claim **16**, wherein the one or more parameters include a first data value.

20. The method of claim **19**, wherein the filtered textual output does not include a portion of the textual output that includes the first data value.

21. The method of claim **19**, wherein the filtered textual output includes a portion of the textual output that includes the first data value and the filtered textual output does not include a portion of the textual output that includes a second data value different from the first data value.

22. A client device comprising:

a user interface (UI) that receives an input comprising an operational command and a selection request, wherein the selection request specifies a field identifier and one or more parameters, and wherein the field identifier maps to a unique element number of an enumeration of a schema identified by the operational command, wherein the schema defines a class of elements that conform to a data description language and is used by a network device to control output of configuration information by the network device, and wherein the enumeration of the schema assigns a unique element number to each element of the defined class of elements;

a network interface that transmits the input to a routing device using a communicative connection, and receives a filtered textual output from the routing device, wherein the filtered textual output forms at least a portion of a textual output solicited by the operational command, and wherein the filtered textual output comprises one or more fields, wherein each field is associated with a unique element number of the enumerated schema, and wherein the filtered textual output is filtered based on the mapping of the field identifier to the enumeration of the

schema and conforms to the one or more parameters specified by the selection request; and

a display device that provides the filtered textual output for display at the UI.

* * * * *